THE STUDY OF ACCIDENTS IN THE AIR FORCE FROM HUMAN FACTORS PERSPECTIVE TO ENHANCE AVIATION SAFETY BY CONSOLIDATION OF COCKPIT RESOURCE MANAGEMENT

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In Taiwan, the military pilot is the major source of civil aviation pilot. The pitfall of military background might be brought up whenever aviation accident took place and the pilot with military experience might take the unfair blame. This study is trying to identify whether there is any difference between the military and civil aviation pilots. Furthermore, to introduce some feasible recommendations to the military authority in order to minimize the gap between these two groups.The investigation collected the latest 20-year accident reports of the Air Force. Content Analysis is practiced to compare different Wings, flying missions and flying hours related to human factors. There is no gap among human, machine and environment in the system so that aviation safety could be secured. Furthermore, the ability to adjust initial error and final error and use all software and human resources would make great contribution to aviation safety in case the emergency occurs. The aims of this survey are: (1) To identify the nature of human errors and potential elements that might jeopardize pilots, crews and aviation organizations. (2) To introduce the concept of CRM to the military organization and make full use of CRM in order to minimize the human errors. (3) The result of this study is expected to produce valuable information to both military and Civil Aviation Authority with the reference to training program of Cockpit Resource Management. (4) To recommend the military authority to establish a "Voluntary Reporting System" with certain waiver of penalties.

Keywords: Human Errors, Human Factors, Content Analysis, Crew Resource Management, Aviation Safety, Zero Accident.

Introduction

During the past few years, a serious of aviation accidents took place for both civil and military aircraft that made aviation safety becoming a hot topic again. For the military aviation, four F-16s and two Mirage 2000s were lost. The Air Force Headquarter wants to improve flight safety via conducting a systematic investigation focused on the recent decade in order to save lives of pilots and valuable fighters. Correct and feasible improving strategy was highly expected. According to the result of this investigation shows the "human factor" takes up 60% of the probable causes among major accidents form 1989 to 1999. From Taiwanese Air Force point of view, single-seat fighter needs no Crew Resource Management (CRM), even there are communication and coordination problems existing between leader and wingman in formation flight. CRM did not get proper attention it deserves. Owing to the CRM negligence, aviation incidents can not be decreased. No matter flight training or combat operation, coordination should be consisted by pilots, navigators, controllers, maintenance-crew and weather officers. According to US A-6 fighter pilot CRM training report, their teamwork performance improved dramatically and the loss rate drop from 7.56 to 0.73 per one hundred hours (Nance, 1998).

The approach of human factors is the systematical application of relevant information about human capabilities, limitations, characteristics, behavior and motivation to the design of things, procedures people use and the environments which they use them. These human behaviors and reactions toward objects and environments' information can be used as the basic foundation of new equipment design. In additions, these information can predict possible effectiveness of different alternative projects. That's why Sanders & McCormick (1987) define Ergonomics as: "Human Factors and applies information about human behavior, abilities, limitations, and other characteristics to the design of tools, machines, systems, tasks, jobs, and environments for productive, safe, confortable, and effective human use." In order to enhance the concept of Ergonomics, Captain Frank H. Hawkins modified Elwyn Edwards' SHELL Model in 1984 (Software, Hardware, Environment and Liveware) and took the most sophisticated & adaptable "human" as the key factor of the system. In the mean time, "Liveware" become the synonym of SHELL model.

Take ergonomics theory to improve CRM effectiveness of the Air Force via modifying software system and hardware equipment in order to create a better environment for human operation. Besides, form recruit to train all aviation related personnel to eliminate the gaps among human, machine and environment. Thus flight safety can be secured. Enable aviation personnel skill and knowledge what they should have by systematic training and establish mistake inspection and standard operation procedure by teaching and instructing. Furthermore, enable pilot with situation awareness and problem solving capabilities between the initiative and the end of unexpected situation take place and can full use of all sofeware, hardware and liveware in order to conduct flight operation safely.

The result of aviation incidents and accidents investigation is one of the basic references to establish CRM theory and training courses. The information of flight safety data can pinpoint the shortfall of flight safety prevention; in additions, can provide some recommendations for accident prevention strategy. This survey collected incidents and accidents investigation reports of the Air Force during the past twenty years. Owing to the reports are official documents and presented in written form which is suitable to use "content analysis" to conduct this survey. Besides, take CRM theory to classify those aircraft mishap reports and verify by Chi-square test. 1. The differences of human factors among different operations. 2. The different patterns of human factors among different Fighter Wings. 3. The different courses of human factors among different ranks.

The statistic analysis shows, there are six distinctive different frequencies of human errors. X^2.211.14, *df*.5, $p<0.001$. Skill base is the highest one (66%); that means two out of three accidents will be caused by this factor. The second and following ones are rule base (41%), leadership base (39%), and judgment base (29%); the least one is communication base among all human factors (10%).

The analysis also shows, different flight operations result in different human errors distinctively. X^2.108.30, *df*.8, $p<0.001$. Interception mission is the highest one among all human errors (23%). In the other hand, solo (5%), formation (6%), and test flight (7%) are the lower ones. The point is different human errors did not show any difference on pattern distribution when tested by the frequency of different missions. X^2.41.81, *df*.40, $p<0.05$. The detailed distribution data is shown in following Table 1.

Table 1.The human error frequency analyzed by different missions

Error Mission	Time	Skill	Rule	Knowledge	Communication	Judgment	Leadership
Tactical	75	51 (68%)	34 (45%)	31 (41%)	6 (8%)	30 (40%)	26 (35%)
Ground Attack	39	32 (82%)	16 (41%)	19 (49%)	5 (13%)	13 (33%)	24 (62%)
Night/ Instrument	61	36 (59%)	24 (39%)	19 (31%)	6 (10%)	21 (23%)	28 (46%)
Performance Take-off/ Landing	48	30 63%	22 46%	16 33%	4 8%	11 23%	23 48%
Test Flight	31	11 (35%)	13 (42%)	12 (39%)	2 (7%)	5 (16%)	6 (19%)
Interception	103	70 (68%)	47 (46%)	45 (44%)	10 (10%)	30 (29%)	32 (31%)
Formation	27	25 (93%)	10 (37%)	16 (59%)	5 (19%)	12 (44%)	21 (78%)
Solo	21	21 (100%)	6 (29%)	12 (57%)	2 (10%)	3 (14%)	19 (90%)
Others	46	28 (61%)	12 (26%)	11 (24%)	4 (9%)	8 (17%)	6 (13%)

X^2.41.81, *df*.40, $p<0.05$.

When analyzed by different Tactical Fighter Wings showed that different human error patterns took place in different wings distinctive difference. X^2.64.67, *df*.9, *p*□0.001. The 9th (17%) and 5th (15%) Wings have the highest human errors' percentage. The 6th and the other Wings (3.6) have lower human errors' percentage. The analysis also showed that different human errors did not show any difference on pattern distribution when tested by the frequency of different Wings. X^2.39.20, *df*.45, $p<.05$. The detailed distribution data is shown in following Table 2.

Table 2.The human error frequency analyzed by different Wings

Error Wing	Time	Skill	Rule	Knowledge	Communication	Judgment	Leadership
1ST Wing	42	26 (62%)	21 (50%)	16 (38%)	4 (10%)	22 (52%)	24 (57%)
2nd Wing	47	27 (57%)	16 (34%)	16 (34%)	5 (11%)	7 (15%)	19 (40%)
3rd Wing	70	43 (61%)	31(44%)	28 (40%)	7 (10%)	20 (29%)	15 (21%)
4th Wing	42	35 (83%)	20 (48%)	20 (48%)	4 (10%)	20 (48%)	22 (52%)
5th Wing	60	42 (70%)	20 (33%)	21(35%)	5 (8%)	15 (25%)	22 (37%)
6th Wing	31	18 (58%)	16 (52%)	12 (39%)	6 (19%)	10 (32%)	15 (48%)
7th Wing	43	21(49%)	11 (26%)	13 (30%)	3 (7%)	5 (12%)	8 (19%)
8th Wing	35	23 (66%)	15(43%)	14 (40%)	2 (6%)	11 (31%)	10 (29%)
9th Wing	77	62 (81%)	33 (43%)	35 (45%)	6 (8%)	17 (22%)	47 (61%)
Others	17	10 (59%)	4 (24%)	7 (41%)	3 (18%)	5 (29%)	3 (18%)

X^2.39.20, *df*.45, $p<0.05$. Note: "Others" consist of by "VIP Air Command" "Air Logistic Command" & "Aviation Development Center" & "Luke AFB, USA".

The following Table 3 analyzed the human error frequency by rank.

Table 3.The human error frequency analyzed by different rank

Error Rank	Time	Skill	Rule	Knowledge	Communication	Judgment	Leadership
Student pilot/2nd Lt	62	47 76%	27 44%	26 42%	6 13%	19 31%	41 66%
1st LT	130	99 (76%)	47 (36%)	62 (48%)	15 (12%)	48 (37%)	61 (47%)
Captain	212	136 (64%)	101 (48%)	83 (39%)	24 (11%)	78 (37%)	90 (42%)
Major	190	111 (58%)	78 (41%)	64 (34%)	23 (12%)	48 (25%)	62 (33%)
Lt Col	97	52 (54%)	33 (34%)	26 (27%)	11 (11%)	25 (26%)	26 (27%)

X^2.16.57, *df*.20, $p<0.05$.

Tactical/Exercise/Interception flight training and Aerial Combat tactical flight are multi-fighter training courses and all these "dog fight" are attack, defense, trace, lock, escape maneuvers which have to experience consecutive hi-G force, location change and three-D maneuvers exercises. Most of all, these are very high tendency of human error circumstances. The probable factors might trigger human errors are as following:

The highly maneuverable property of jet fighter would let physiological tolerance of human to acceleration be easily exceeded, resulting in G-induced loss of consciousness due to insufficient cerebral blood flow and cause aviation accident. Anti-G suit wear out or disconnected resulting in G-induced loss of consciousness, flight skill could not handle flight operation properly, and predict the other fighter probable flight path in time in order to take suitable action to the situation. Pilot did not fully understand sophisticated systems of the aircraft, thus when emergency took place pilot could not use systems or procedures effectively and made wrong decisions. Over the structural limitations of the aircraft, for example "over-G" is the most common issue in Aerial Combat tactical flight and resulting in structural damage. When focused on operating, tracing, and locking aircraft might under estimate potential risks by oversight the environment, for example flight into cloud resulting in space disorientation or poor situation awareness.

Night/Instrument flight has a higher human error rate due to its unique external environment, such as darkness of night, cloud, fog, rain which cannot conduct visual flight. The probable courses are: Pilot rather rely on their physical feeling than instruments, cabin luminous system misused, too many head moments caused disorientation and resulting in spin and/or spiral. Fatigue, flue, vitamin shortage, smoking, alcohol consuming, and drug might affect night vision.

From Table 2 the 9th and 3rd Wings showed higher human error rate, and the 6th Wing lower. The analysis results were these two AFBs are playing a major role in training missions, and the lower one is focusing on transporting, anti-submarine, and electronic warfare missions which need violent maneuvers exercises less.

Table 3 rank analysis showed captain and major are the key players of squadron no matter combat, exercise and training missions; these resulting in higher human error rate as well. In additions, owing to these two ranks are veteran pilots and this might make them reducing their risk alert and/or too confident on flight capabilities of themselves. Furthermore, they might ignore some flight limitations and rules for the same reason.

How to prevent effectively and reduce human factors of aviation incidents and accidents? There are several recommendations as following:

Boost "Crew Resource Management" education in a full scale and take "localization" as the key point of the design of training content. In another words, Taiwanese Air Force pilots' forming background, organizational culture, habitual communicational pattern, go along with the case studying, reinforcing via "safety recognition" and "risk management" in order to build up and ensure a "zero-accident" creative organization culture.

1. Develop a concrete rating/reporting system in order to promote flight skill and training performance. The only way of promoting flight skill is practicing repeatedly. Thus, to stop the final domino of "flight safety cheese". It takes not only hardworking training attitude but also essence and effectiveness of quality control to develop a concrete rating/reporting system. Take Table 1 "solo" as an example, skill result in error is 100%; that means it takes precise and strike evaluation via the rating system in order to establish pilot's capability to conduct specific mission. In addition, not to make unreal training rate to meet the combat readiness' criterions and result in ignoring the goals of flight skill specialties and flight safety because safety concern is beyond all emotions.

2. Stick to the training standards of body fitness of pilots: Pilot tends to respond unexpected situations at all time quickly. “Heavy-weight training” and “aerobic exercises” can reinforce anti-G capability and high-G endurance. It takes the Air Force authority to establish a flight safety policy and training standard to build up such a capability of pilots in order to reduce the G-lock situation.
3. To build up a non-penalty (confidential) reporting system: There are various factors to result in an aircraft accident. It’s not an easy job to rebuilt the true cause and effect of the accident. A non-penalty (confidential) reporting system provide a availability of limited immunity provided incentive to reporters with little risk to reveal the vital truth. Thus, via the truth to find out the closest possible causes of the incident/accident in order to prevent the same error happen again. This will help the high-ranking officials to make strategic policies of risk management and accident prevention.

This study is taking the human factor point of view and content analysis method to analysis human error of flight accidents. Furthermore, this study focus on different missions, organizations, and ranks to analysis the source of accident in order to establish a localized CRM theory and training course. Taiwan Air Force did pay to much attention to CRM and human factor studies which resulted in a lose control of flight safety events, great loss of human lives and costs and the image of the Air Force. This study is one of the pilot studies of aviation accidents from human factors perspective. Hopefully, this study will contribute some positive effects on improving current flight safety and reach “zero accident rate” in the future.

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